

## COVER NOTE

## The Bird Ventilator



Left to right: Bird 4A anaesthesia ventilator and Bird Mark 7A ventilator.

Forrest Bird was born in Stoughton, Massachusetts, in 1921. His father had been a World War I pilot and encouraged the young Forrest to fly. He took his first solo flight at the age of 14<sup>1</sup>. By 16 he was an experienced pilot, and during World War II he joined the US Army as a pilot and Technical Air Training Officer. Part of his role was to deliver aircraft from the factory across the North Atlantic to the front. This enabled him to experience flying most of the aircraft available at the time. In total, Bird has flown jet aircraft, helicopters and gliders as well as a huge variety of propeller driven aeroplanes. His enthusiasm for aviation remains unabated and he is still flying the 1938 Piper Cub that belonged to his father. However, it was the invention of a positive pressure ventilator that made Bird an international household name<sup>2</sup>.

His first invention was a device to assist breathing for pilots at high altitude. Bird was instructed to fly a captured German Junkers JU-88 back to the US so that it could be studied. The German plane was equipped with an oxygen delivery system so the crew could fly at high altitudes, much higher than the 28,000 feet achieved by allied aircraft using a standard free-flow Boothby-Lovelace-Bulbulian oxygen mask. Bird adapted pressure gas masks used in mines to produce positive pressure oxygen facemasks which were successful up to 35,000 feet<sup>1-3</sup>.

Towards the end of World War II, military jet aircraft were becoming increasingly fast and manoeuvrable resulting in high g-forces and pilot blackouts. In response, Bird developed an anti-g suit for pilots. His increasing interest in human physiology led colleagues to suggest that he enter medical school. However, it was not until Bird suffered ocular haemorrhages after a human centrifuge malfunction during a g-suit test that he decided to pursue his MD<sup>3</sup>.

He became fascinated by respiratory physiology, likening the pressure effects of air flowing over aerofoils to gas flow in the lungs. "In that lung are rudimentary air foils. It's like a million airplane wings all down through the lungs ...", he said. In 1947, he adapted a military oxygen breathing regulator to produce a manually controlled positive pressure breathing device in order to help a friend's father who was suffering from emphysema. He obtained a doorknob from a hardware store and that became the control knob. The patient would place their mouth on the mouthpiece and push on the knob in order to inflate their lungs<sup>2</sup>.

At this time there were few devices able to assist people with respiratory failure apart from iron lungs, which were cumbersome and expensive, and there was limited enthusiasm among surgeons and anaesthetists for controlled ventilation during surgery. In Scandinavia and Britain, anaesthesia ventilators began to appear, including Mörch's, Pinson's and the Blease, stimulated by the introduction of muscle relaxants. The US was slower to adopt the idea. Trier Mörch, who relocated from Denmark to the US, wrote, "as late as 1951, when I became head of the Department of Anesthesia at the University of Chicago, I was told by a surgeon on the staff, 'NO endotracheal tube, NO controlled respiration, NO curare, and—naturally—NO automatic breathing machines'<sup>4</sup>".

Bird wanted to develop a smaller more affordable device to assist breathing. In his positive pressure breathing device and anti-g suit regulator he had the workings of an intermittent positive pressure ventilator. The anti-g suit regulator used a magnetic clutch and together with some strawberry shortcake tins and the positive pressure regulator he was able to develop a prototype ventilator. Initially called the Bird Residual Breather, it went through six prototype stages before being

released commercially as the Bird Mark 7 Respirator in 1957, just as anaesthetists were adopting controlled ventilation techniques<sup>1,5</sup>.

The Bird Mark 7 Respirator is powered by oxygen or compressed air at a range of supply pressures. It is a non-rebreathing ventilator designed to deliver the driving gas with or without entrained air to the patient. Inspiration, can be cycled automatically or patient triggered. The ventilator functions as either a flow generator or pressure generator in inspiration depending on whether air entrainment is in use or not. Inspiratory pressure can be adjusted between 5 and 60 cmH<sub>2</sub>O. The changeover from inspiration to expiration is pressure cycled and from expiration to inspiration by time. The flow of gas into the breathing circuit is controlled by a sliding ceramic valve, the movement of which is determined by plates and magnets at each end. The detailed operation can be understood by referring to *Automatic Ventilation of the Lungs*<sup>6</sup>.

Several developments followed the Mark 7. The Mark 8 included the provision for negative pressure during expiration. The Mark 9 allowed much higher pressures (up to 260 cmH<sub>2</sub>O) and flows during inspiration and was famously used by the San Diego Zoo to ventilate an elephant<sup>5</sup>. The Mark 10 included a flow accelerator or leak compensating system and the Mark 14 deleted the air entrainment control. The Mark 17 incorporated a sensing band around the patient's chest to provide a "volume cycling" option<sup>6</sup>.

The Bird Mark 4 is not a ventilator on its own, but a bag-in-bottle assembly to allow a Mark 7, 8 or 10 ventilator to be adapted for use during anaesthesia. The later Mark 4A combined the bag-in-bottle and ventilator features to become a freestanding anaesthesia ventilator.

The Bird Mark 2 ventilator was developed in the early 1970s in order to intermittently compress an anaesthesia reservoir bag within a clear plastic outer bag. This was a small and simple device using the principle of fluidics rather than a magnetic clutch<sup>6</sup>. The same principle had been used in the Babybird ventilator of 1969. This neonatal ventilator was used to successfully treat respiratory distress syndrome in infants and led to a substantial decrease in mortality<sup>1,5</sup>. As a result, the Bird Mark 7 Respirator and its derivatives became some of the most widely used ventilators in the world and are still in use in many places today.

In 1976, the global spread of Bird ventilators prompted the Bird Corporation insurer to refuse to continue indemnity insurance despite an unblemished litigation history. In 1978, Bird merged his Corporation with the much larger 3M company and continued his passion for invention and respiratory control independently. At his research centre in Idaho, he developed his fourth generation of ventilators using the principle of high frequency ventilation, also known as intrapulmonary percussive ventilation<sup>5</sup>. Bird's experiences with helicopter and fixed wing casualty evacuation during the Vietnam War led him to adapt the Mark 14 ventilators to intensive care air transportation including his own Lear jet<sup>5</sup>.

Bird has been honoured with admission to the US Inventors Hall of Fame, the Presidential Citizens Medal and the National Medal of Technology, among others. He still flies and maintains an aviation museum and display with 21 operational aircraft. When asked how one person can use all those planes, he replied "one at a time"<sup>2</sup>.

R. N. WESTHORPE, C. BALL

Geoffrey Kaye Museum of Anaesthetic History

## References

1. Rendell-Baker L, Mayer JA, Bause G. Pioneers and Innovators in Anaesthesia. In: Esch JS and Goerig M (Eds). Proceedings, The Fourth International Symposium on the History of Anaesthesia. Lübeck, Germany: Dräger Druck GmbH & Co. 1998.
2. Forrest Bird. The Birdman of Idaho. CBS News. From: [www.cbsnews.com/stories/2009/08/19/60minutes/main3334433.shtml?tag=currentVideoInfo;videoMetaInfo](http://www.cbsnews.com/stories/2009/08/19/60minutes/main3334433.shtml?tag=currentVideoInfo;videoMetaInfo). Accessed 30 August 2009.
3. Hamonet C. Forrest Morton Bird or the story of an inventive aviator and respiratory physiologist. From [www.claude.hamonet.free.fr/eng/art\\_bird.htm](http://www.claude.hamonet.free.fr/eng/art_bird.htm). Accessed 11 May 2009.
4. Mörch ET. History of Mechanical Ventilation. In: Kirby RR, Smith RA, Desautels DA (Eds). Mechanical Ventilation. New York: Churchill Livingstone 1985.
5. Historical briefs leading to four generations of aeromedical devices conceived and developed by Forrest M Bird MD PhD ScD. Bird Institute of Biomedical Technology 2005.
6. Mushin WW, Rendell-Baker L, Thompson PW and Mapleson WW. Automatic Ventilation of the Lungs. 2nd Edition. Oxford and Edinburgh: Blackwell Scientific Publications 1969.